

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An imaging endoscope, comprising:
  - a shaft having a proximal end and a distal end and one or more lumens therein;
  - one or more light emitting diodes (LEDs) at or adjacent the distal end of the shaft for illuminating tissue;
  - an imaging assembly at the distal end of the shaft that includes an imaging sensor to produce an image of the tissue;
  - a number of control cables that are selectively tensioned to bend the shaft in a desired direction;
  - a deformable articulation joint that includes a number of links that are joined together with spring segments and are bendable under tension of one or more of the control cables; and
  - a sheath over the articulation joint.
2. The imaging endoscope of Claim 1, wherein the control cables pass through the spring segments that join adjacent links together.
3. The imaging endoscope of Claim 1, wherein each link includes a front surface and a rear surface each of which has a pair of sloped surfaces thereon such that the sloped surfaces from adjacent links allow increased bending of the links.
4. The imaging endoscope of Claim 1, wherein the spring segments that join the links together have a uniform pitch.
5. The imaging endoscope of Claim 1, wherein the spring segments that join the links together have alternating tightly wound and loosely wound sections.
6. The imaging endoscope of Claim 5, wherein the shaft includes a breakout box having an entrance to a working channel of the endoscope therein, the shaft having a greater torque fidelity distal to the breakout box than proximal to the breakout box.

7. The imaging endoscope of Claim 1, further comprising a connector at the proximal end for connecting the endoscope to a control cabinet, the connector including:

- one or more spools on which ends of the control cables are wound;
- a manifold that routes a liquid to different lumens in the endoscope; and
- an electrical connector for passing signals to and from the image sensor.

8. The imaging endoscope of Claim 7, wherein the manifold comprises two sheets of thermoplastic material that are bonded together to form passages therein that direct liquids to different lumens in the endoscope.

9. The imaging endoscope of Claim 7, wherein the connector includes two spools, each of which has two control cables wound thereon.

10. The imaging endoscope of Claim 7, wherein the connector has three spools, each of which has a control cable wound thereon.

11. The imaging endoscope of Claim 7, wherein the connector has four spools, each of which has a control cable wound thereon.

12. A single use endoscope that is removably connectable to a reusable control unit to form a system for examining an internal body cavity of a patient, comprising:

- a shaft having a proximal end, a distal end and a number of lumens therein;
- an articulation joint at or adjacent the distal end for allowing the distal end of the shaft to be selectively oriented;

- a number of control cables that pull the articulation joint in a desired direction;
- an imaging assembly at or adjacent the distal end of the shaft to produce images of the internal body cavity, the imaging assembly including:

- a cap having at least one illumination port through which illumination light may pass and an imaging port; and

- a heat exchanger assembly including one or more light emitting diodes mounted therein, a cooling channel in thermal contact with the light emitting diodes, a lens assembly and a solid state imaging device, wherein the heat exchanger assembly is insertable into the cap.

13. The single use endoscope of Claim 12, wherein the cap of the imaging assembly includes two illumination ports, each having a window which is molded into a front face of the cap.

14. The single use endoscope of Claim 12, wherein the heat exchanger includes a cylindrical recess into which a cylindrical lens assembly is fitted in order to retain the lens assembly in the heat exchanger.

15. The single use endoscope of Claim 13, wherein each window of the illumination port is coated with a phosphor.

16. The single use endoscope of Claim 15, wherein the phosphor is applied to an inside surface of the illumination port windows with an adhesive.

17. The single use endoscope of Claim 15, wherein the image assembly includes a cable having at least two shielded leads for transmitting image signals from the solid state imaging device differentially.

18. An imaging endoscopic system, comprising:

a control cabinet including a number of actuators that operate to control the orientation of an endoscope;

an image processor board for creating images received from signals produced by an image sensor in an endoscope;

a display for displaying images of tissue;

one or more valves to control the delivery of an irrigation fluid, insufflation air/gas and vacuum to one or more lumens in an endoscope;

a handheld controller including a number of controls that can be activated by a physician to supply commands to the control cabinet; and

a single use endoscope that is removably connectable to the control cabinet, the endoscope including:

a shaft with a proximal end and a distal end and one or more tubes or lumens therein;

one or more light emitting diodes to provide illumination light for illuminating tissue;

an image sensor at the distal end of the endoscope for producing images of tissue;

an articulation joint including a number of stacked segments that are joined together with spring segments to allow adjacent segments to bend relative to each other; and

a number of control cables having distal ends secured to the articulation joint and proximal ends that are selectively tensioned by the actuators to orient the distal tip of the endoscope.

19. The imaging endoscope system of Claim 18, wherein the control cables have an outer sheath having ends that remain fixed as the control cables are tensioned.

20. The imaging endoscopic system of Claim 18, wherein the endoscope is removably connected to the control cabinet with a connector that includes a number of spools to which the control cables are connected and a manifold for selectively directing air, water or vacuum to one or more tubes or lumens in the endoscope.

21. The imaging endoscopic system of Claim 18, wherein the handheld controller is connected to the control cabinet through a wired link.

22. The imaging endoscopic system of Claim 18 wherein the handheld controller is connected to the motion control cabinet through a wireless link.

23. The imaging endoscopic system of Claim 18, wherein the handheld controller provides tactile feedback to the user that is proportional to the force required to move the distal tip.

24. The imaging endoscope system of Claim 23, wherein the control cabinet includes a processor that separates a force required to move the shaft from a force required to move the distal tip, and wherein the tactile feedback provided to a user is proportional to the force required to move the distal tip.

25. The imaging endoscope of Claim 18, wherein the control cabinet includes a processor that determines a force on the endoscope and compares it to a variable braking threshold, the processor causing the actuators to move the distal tip of the endoscope such that the force is less than the braking threshold.

26. The imaging endoscope system of Claim 18, wherein the control cables are made of metal.

27. The imaging endoscope system of Claim 18, wherein the control cables are made of PET.

28. The endoscope of Claim 18, wherein the shaft is coated with a hydrophilic coating and the shaft further includes a gripper that can be wetted to activate the hydrophilic coating.

29. A handheld controller for operating a steerable endoscope, comprising:

a handle;

a number of buttons disposed on the handle for controlling the functions of an endoscope;

a directional controller for entering commands that cause a distal tip to move in a desired direction; and

a feedback mechanism coupled to the directional controller for providing tactile feedback to a user of a force required to move the distal tip of the endoscope.

30. The handheld controller of Claim 29, wherein the directional controller is a joystick and the feedback mechanism selectively adjusts the tension of a spring on the joystick.

31. The handheld controller of Claim 29, wherein the directional controller is a joystick that is movable with at least two motors and the feedback mechanism selectively adjusts the torque of the two motors.

32. An imaging system for use with an endoscope, comprising:

a cap having a front face having openings therein for illumination light and an image sensor;

a heat exchanger that is fitted within the cap, the heat exchanger including at least one or more light emitting diodes mounted thereon; an image sensor secured thereto; a channel in thermal contact with the one or more light emitting diodes; and a recess into which a lens assembly is fitted and aligned with the image sensor.

33. The imaging system of Claim 32, wherein the front face of the cap has windows therein that are aligned with the light emitting diodes mounted on the heat exchanger.

34. The imaging system of Claim 33, wherein the windows have a phosphor coating on an inside surface thereof.

35. The imaging system of Claim 34, wherein the phosphor coating is mixed with an epoxy.

36. The imaging system of Claim 35, wherein the epoxy is curable with an ultraviolet light shown through the windows of the cap.

37. The imaging system of Claim 32, wherein the cap has a flushing port molded into a front face of the cap that directs a flushing liquid over the lens assembly.

38. A single use endoscope that is removably connectable to a reusable control cabinet to form a system for examining an internal body cavity of a patient, comprising:  
a shaft having a proximal end, a distal end and one or more lumens therein;  
an articulation joint adjacent the distal end of the shaft for allowing the distal end of the shaft to be selectively oriented;  
a number of control cables that are tensioned to pull the articulation joint in a desired direction; and

a connector at the proximal end of the shaft for removably connecting the endoscope to the control cabinet, the connector including a manifold that directs an irrigation fluid to be selectively delivered to one or more lumens in the shaft.

39. The single use endoscope of Claim 38, wherein the manifold comprises a flexible bag having a number of passages therein through which the irrigation fluid can flow.

40. The single use endoscope of Claim 39, wherein the passages are opened and closed with one or more valves that pinch or release the passages in the flexible bag.

41. An endoscope for use in imaging an internal body cavity of a patient, comprising:

a shaft having a proximal end and a distal end and one or more lumens therein;  
means disposed at or adjacent the distal end for allowing the distal end of the shaft to be directed in a desired direction by a number of control cables;  
an imaging means disposed at the distal end of the endoscope for illuminating tissue inside a body cavity and producing images of the body cavity;  
means for selectively coupling the proximal end of the shaft to a reusable control cabinet; and  
means for selectively directing an irrigation liquid and an insufflation gas into one or more lumens of the endoscope.

42. The endoscope of Claim 41, wherein the means for selectively directing an irrigation liquid and insufflation gas in one or more lumens of the endoscope comprises a disposable, flexible bag having passages therein that connect an irrigation liquid to the one or more lumens of the endoscope and wherein the passages are selectively opened and closed by valves on the control cabinet.

43. The endoscope of Claim 41, wherein the imaging means comprises:

a cap having at least one illumination port and imaging port therein;

a heat exchanger having one or more light emitting diodes mounted thereon, a channel through which a cooling media can be passed to cool the one or more light emitting diodes;

an imaging sensor to produce images; and

a channel that aligns a lens assembly with the imaging sensor.

44. The endoscope of Claim 41, wherein the illumination port includes a means for producing white illumination light from the light produced by the one or more light emitting diodes.

45. The endoscope of Claim 44, wherein the white light producing means is a phosphor coating on the illumination port.

46. The endoscope of Claim 45, wherein the phosphor is adhered to the illumination port with an ultraviolet light curable adhesive.

47. The endoscope of Claim 43, wherein the cap includes a molded flush cap that directs an irrigation fluid across a lens.

48. The endoscope of Claim 41, wherein the means for allowing the distal end of the shaft to be directed in a desired direction comprises a number of stacked links that are joined together with spring segments.

49. The endoscope of Claim 48, wherein the spring segments have a uniform winding pitch.

50. The endoscope of Claim 48, wherein the spring segments have alternating sections of tightly wound and loosely wound sections.

51. The endoscope of Claim 41, wherein the means for selectively coupling the proximal end of the shaft to the control cabinet includes at least two spools on which the control cables are wound, the spools engaging a motor in the control cabinet when the shaft is coupled to the control cabinet.

52. The endoscope of Claim 41, further comprising means for grasping the shaft to move the shaft within the patient.

53. The endoscope of Claim 51, further comprising:  
means for determining a force required to move a distal tip of the shaft and means for supplying a feedback signal to a user that is proportional to the force required to move the distal tip of the shaft.

54. The endoscope of Claim 51, wherein the control unit selectively moves the distal tip in a number of directions and estimates a force to move the shaft and a force to the distal tip of the shaft, wherein the force to move the distal tip is supplied to a feedback device that produces a tactile signal back to a user that is proportional to the force required to move the distal tip.

55. An imaging endoscopic system, comprising:  
a control unit having a number of actuators therein for selectively tensioning control cables of an endoscope secured thereto;  
each actuator having a sensor for measuring forces on a control cable driven by the actuator; and  
a processor that compares the force on a control cable with a variable braking threshold and that causes the number of actuators to move a distal tip of the endoscope to a position such that the force on the control cable is less than the variable braking threshold.